REMARKS

The previously *Pro Se* Applicants in the above-noted application have decided to obtain professional assistance with this application and have accordingly appointed our firm as their Attorney of Record. Copies of the Power of Attorney documents are submitted herewith.

The Applicants have amended the specification, abstract and claims of this application to overcome the Examiner's objections raised in the Office Action mailed 21 January, 2005.

In respect of the **specification**, the Applicants have added a sentence to page 1 supplying the particulars of the provisional application from which this application claims priority, as requested by the Examiner.

In respect of the **abstract**, the Applicants have provided a replacement abstract which is only one paragraph in length and which has fewer than the allowable number of words.

In respect of the **claims**, the Applicants have cancelled all of the previously-pending claims and have added new claims 15-34 to more clearly distinguish the invention from the prior art cited by the Examiner and from other known prior art. Many of the new claims are similar to one or more of the old claims; however, it was thought that it was more appropriate, for efficiency, clarity and expediency, to simply supply an entirely fresh claim set than to attempt to amend the old claim set. The claims are not to be considered to have been amended or more particularly narrowed in view of the prior art cited by the Examiner, but rather have been replaced with new claims which have been prepared by a patent attorney familiar with patent law and practice to more appropriately define and reflect the invention made by the inventors, and to more clearly distinguish that invention from the prior art.

The Applicants submit that the new claims now more clearly define the invention essentially as a method and system for determining one or more surface profiles of an object. The object is moved relative to sensors, and the sensors take distance measurements, providing distance measurement data. The sensors are arranged to provide this data for one ore more surfaces. The distance measurement data has a first component relating to the particular actual surface profile features of the object and a second component relating to rigid body relative motions of the object in the measurement direction relative to the sensors (which can be significant as the object, if a piece of

lumber, for example, is measured as it "bounces" along a conveyor system).

The Applicants have determined that it is possible to calculate this second component of the distance measurement data, and have understood that once it is subtracted from the distance measurement data, the remaining data reflects only the surface features of the object. This rigid body relative motion component of the measurement data is calculated by identifying motion fluctuations of the object measured simultaneously at the sensors. This method and system is new and not obvious in view of any prior art that the applicants are aware of.

For completeness, the Applicant provides the following comments relating to the prior art cited by the Examiner:

Noss: US Patent 5,280,719 (Noss) describes a device with a similar purpose to that of the system of the present invention. The Noss device uses a plurality of distance measuring sensors. However, in most other respects it is different than the present invention, as now claimed. The Applicant submits that the Noss device has lesser capabilities than the present device as now claimed. The question of "capability" involves two considerations that distinguish the two systems: the capacity to identify small details in the measured surface, and the capacity to identify features spread over large distances. To measure small details, a small distance between measurements is needed, while to measure spread-out features, a sensor array of large overall length is required. The device disclosed by Noss comprises several sensors arranged with equal spacing, and with the requirement that measurements are made at integer multiples of the sensor spacing. In this arrangement, the spatial resolution of the device equals the sensor spacing; no surface feature smaller than this can be resolved. The capability to identify spread-out features is controlled by the length of the sensor array. Thus, to have the capability to identify a wide range of surface feature sizes requires a set of sensors, closely spaced, and sufficiently numerous to cover a large overall length. Noss does not specify a definite number of sensors required. However, Noss's Figures 1 and 2 indicate 17 sensors, suggesting the practical need for many sensors.

The system of the present invention overcomes this limitation by using measurements made at a fractional distance between sensors (as now clearly claimed in new claim 15). The experimental measurements of the present system have used up to about 50 measurement steps within the sensor spacing. This greatly increases the ability to resolve small surface details while still using a small number of sensors, for example four sensors in Figure 2. Further, in contrast to Noss, the present system does not require equally spaced sensors.

In practice, equally spaced sensors in the present invention would not be preferable. Rather, as shown in Figure 2, it is preferable to have unequal spacing between adjacent sensors in the present system.

Nelson et al. (US Patent 6,427,353) describe a device that uses distance measurement sensors placed in pairs on opposite sides of a rotating object. The main purpose of this arrangement appears to be to identify the thickness and longitudinal surface shape of the measured object. The combination of measurements from a pair of sensors on opposite sides of an object identifies the local thickness, but no use is made of previous or subsequent measurements. The principle of operation of the Nelson device is fundamentally different from that of the present system, and it cannot measure individual surface profiles, only thickness profiles. In contrast to Nelson, the present systems does not require all sensors to be in pairs exactly opposing each other. Again, in the present system, this arrangement would in fact be the worst possible choice. The Examiner will note the offset between sensors b and e shown in Figure 4.

Finally, **Ohtsuka** (US Patent 6,701,633) describes a device that uses distance sensors placed so that they measure along parallel lines on the surface of an object. This invention appears to have a different purpose than that of the present system. Only one measurement is made along each line. Since there are no repeated measurements, there is no capacity at all to compensate for unknown rigid-body motions. In addition, each measurement is used independently, with no connection being made among the measurements from the various sensors. The only purpose of the multiple sensors is to multiply the amount of data available, without any effect on surface measurement quality. In contrast, in the present invention, the data from the parallel lines of sensors (in Figures 5 and 6) are very substantially combined to identify the surface shapes along those lines. This data combination excludes the effects of rigid-body motions, and thereby greatly improves the surface measurement quality.

Finally, in respect of all of the cited prior art, the applicant notes that the use of or need for any kind of regularization is not mentioned, even briefly, or even suggested.

The Applicant notes, finally, that the present application was accorded a filing date of March 18th, 2004. The applicants, as individuals not represented by any attorneys, mailed the formal application documents to the USPTO on March 15, 2004, and a copy of the post office receipt is attached as proof of the mailing date. The applicants respectfully request that the filing date accordingly be identified as March 15th, 2004.

It is believed that all of the Examiner's objections have been obviated by the amendments to the specification, abstract and claims, and the applicants respectfully submit that this application is now in condition for allowance. The Examiner is invited to contact the undersigned by telephone or e-mail if the Examiner wishes to discuss any issues further.

Respectfully submitted,

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SURFACE PROFILE MEASUREMENT, INDEPENDENT OF RELATIVE MOTIONS

ABSTRACT

A general method is disclosed for using distance sensors to measure the surface profile and twist of objects, even in the presence of rigid-body motions in the measurement directions between the surface and the sensors. The method involves making multiple sequential measurements from a group of sensors while the object moves longitudinally relative to the sensors. The surface height features of the measured object appear in delayed sequence as the observed surface moves longitudinally relative to the sensor array. However, any rigid-body motions in the measurement directions appear simultaneously at all sensors. Mathematical procedures are used to separate the delayed and simultaneous components of the measurements, from which the surface height profile is determined. The invention can handle many different measurement types, including simultaneous measurement of the surfaces of two-sided objects, measurement of surface twist and two-dimensional surface scanning.

TECHNICAL FIELD

This application claims priority from US Provisional Application 60/454,603 entitled "Surface Profile Measurement, Independent of Relative Motions" filed March 17, 2003."

This invention relates to a method and apparatus that can measure the surface profile and twist of one or both sides of an object that is moving longitudinally relative to the apparatus, independent of rigid-body motions in the measurement direction. Such measurements are useful for surface quality control of manufactured products, for example sawn lumber and rolled metals, and for extended surfaces such as railroad rails and highway pavements.

BACKGROUND OF THE INVENTION

Surface profiling is an important need in many industrial and scientific applications. Typical examples include flatness inspection of railway rails and road surfaces, and quality control of manufactured products such as sawn lumber and rolled metal.

The simplest way to measure surface height profile is to make a series of measurements with a distance sensor while relatively moving the measured object and the sensor in a straight line perpendicular to the measurement direction. FIG. 1(a) schematically shows an example arrangement. The drawback to this method is that deviations from straight-line motion cause relative displacements in the measurement direction that are indistinguishable from measured surface shape. Thus, very accurate linear motion is essential.

In many cases, accurate linear motion is not practicable. For example, when measuring the surface profile of a long length of railway track, it is not feasible to provide a separate linear slide for moving the sensor. Instead, the sensor must travel on the irregular track that it is measuring. Existing non-inertial techniques focus on the surface curvature because it can be identified independently of relative displacements or rotations. A typical arrangement uses three or more sensors operating simultaneously, as shown in FIG. 1 (b). US Patent 4,288,855 describes examples of this concept. The sensors estimate the local surface curvature from the second finite difference of their measurements. The curvature values are integrated twice to determine the surface profile. This method is effective, but it has difficulty resolving surface features that are either greatly shorter or greatly longer than the total spacing of the sensors.

US Patent 5,280,719 describes an apparatus that uses a large number of equally spaced sensors. The apparatus seeks to identify long surface features by overlapping sets of